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Wheat Effect on Frost-Seeded Red Clover Cultivar Establishment and Yield

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ABSTRACT

Frost-seeding red clover (*Trifolium pratense* L.) into winter cereals is a cost effective establishment method. Abiotic effects on seedling establishment have been reported, but information on cultivar differences is lacking. The objectives of this study were to quantify the effect of winter wheat (*Triticum aestivum* L.) on the establishment, persistence, and forage dry matter (DM) production of 15 red clover cultivars of diverse origin. Cultivars were frost-seeded near Ames, IA in March of 2003 and 2004 and Prairie du Sac, WI in 2004. Presence of the wheat crop caused 19 and 23% mortality in 2003 and 2004 compared with the no-wheat treatment in Iowa and 51% mortality in 2004 in Wisconsin. Dry matter yield of diploid cultivars exceeded tetraploids in all environments (439 vs. 559 g m^{-2}). Favorable conditions for germination and emergence in 2003 resulted in high plant densities and no relationship between post-wheat red clover density and DM yield. In 2004, unfavorable environmental conditions reduced plant densities, creating a relationship between red clover density (x) and DM yield (y) (y = 305 + 8.86x, R^2 = 0.65 in Iowa; y = 382 + 3.83x, R^2 = 0.22 in Wisconsin). The southern cultivar Cherokee generally had greater performance than the average northern cultivar. Differences across years and locations were inconsistent for elite and land races. Within different origins and selection histories, large variability exists in cultivar performance. More data are needed to determine if the cultivar-by-wheat interaction is important for screening cultivars for dual grain/forage systems.

Red clover is interseeded in winter cereal systems at northern latitudes for forage (Sustainable Agriculture Network, 1998), for weed suppression (Mutch et al., 2003), and as a nitrogen (N) source (Bruulsema and Christie, 1987; Hesterman et al., 1992) for corn (*Zea mays* L.). Although red clover is considered shade tolerant, extreme shading occurs in a cereal canopy that is harvested for grain. Smith et al. (1985) recommended reducing the seeding rate of the small grain by 50 to 75% to obtain a good stand of red clover. They also state that it may be desirable to harvest the small grain early as a hay or silage crop before it smothers the clover.

Recent studies have demonstrated that a wheat/red clover year in the corn-soybean [*Glycine max* (L.) Merr.] rotation is economically competitive with continuous corn, soybean followed by 2 yr of corn, and a corn–soybean rotation, depending on tillage and marketing the wheat straw (Singer and Cox, 1998b; Katsvairo and Cox, 2000). Little published information is available comparing establishment and forage DM production of red clover cultivars. Mutch et al. (2003) reported a seeding rate-by-cultivar interaction in 1 of 2 yr in a Michigan study comparing the effectiveness of different frost-seeded cultivars on weed suppression following winter wheat. Hesterman et al. (1992) reported no difference between 'Michigan Mammoth' and medium red clover for plant density, fall herbage, fall roots, spring herbage, spring roots, or plowdown N yield in a Michigan study where the red clover remained undisturbed for the duration of the growing season after wheat harvest.

Agronomic information is available for red clover cultivar selection, but information comparing cultivar performance in a winter cereal interseeding is lacking. Singer and Cox (1998a) reported that red clover establishment in years with dry springs was poor, but they used only one cultivar. Identifying red clover cultivars with greater establishment and low mortality under dense cereal canopies may improve subsequent forage DM production. Sturz et al. (2003) evaluated different red clover and potato (*Solanum tuberosum* L.) cultivars for red clover-potato combinations for improved potato yield. They detected a specific combination that increased tuber yield. To the best of our knowledge, limited work comparing red clover cultivar performance (establishment and yield) in winter cereal systems has been conducted. The objectives of this study were to quantify the effect of winter wheat on the establishment, persistence, and forage DM production of 15 red clover cultivars of diverse origin.

MATERIALS AND METHODS

Field studies were conducted near Ames, IA at the Iowa State University Agronomy and Agricultural Engineering Research Farm (42°01′ N, 93°45′ W) and near Prairie du Sac, WI (43°20′ N, 89°23′ W). Soil type in 2003 was a Nicollet clay loam (fine loamy, mixed, mesic, Aquic Hapludoll) and in 2004 was a Canisteo silty clay loam (fine-loamy, mixed, superactive, calcareous, mesic Typic Endoaquolls) near Ames, IA and a St. Charles silt loam (fine-silty, mixed, superactive, mesic Typic Hapludalfs) near Prairie du Sac, WI. Soil test results in 2003 were 12 mg kg^{-1} P (Bray P), 80 mg kg^{-1} K (ammonium acetate), and a pH of 7.0. In 2004, soil test results in Iowa were 12 mg kg^{-1} P, 120 mg kg^{-1} K, and a pH of 7.4 and 38 mg kg^{-1} P, 189 mg kg^{-1} K, and a pH of 6.8 at the Wisconsin site.

The experimental design was a randomized complete block in a split-plot arrangement with four replicates. Red clover cultivar was the main plot, with the presence or absence of wheat as the subplot. Subplots were 1.48 m^2 in size. Red clover cultivars were selected that represented Elite Southern, Elite Northern, Wisconsin Elite, Eastern Land Race, Wisconsin Land Race, and tetraploid populations (Table 1). Cultivars were chosen from a population of over 200 red clover cultivars collected from North American and European breeding programs. Six groups were defined based on differences in ploidy

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Abbreviations: DM, dry matter.

Table 1. Red clover cultivar description.

Cultivar	Ploidy	Origin†	Selection history
AC Endure	Diploid	Northern	Elite
C328	Diploid	Wisconsin	Elite
Cherokee	Diploid	Southern	Elite
Chesapeake	Diploid	Eastern	Land race
Cinnamon	Diploid	Northern	Elite
Dolina	Tetraploid	European	Elite
HC-11	Diploid	Wisconsin	Land race
Marathon	Diploid	Wisconsin	Elite
Pennscott	Diploid	Eastern	Land race
Ram	Diploid	Northern	Elite
Robust II	Diploid	Northern	Elite
Scarlett	Diploid	Northern	Elite
Sienna	Diploid	Northern	Elite
Starfire	Diploid	Northern	Elite
Wis4x	Tetraploid	Wisconsin	Elite

† The division between northern and southern groups in North America was 37° N lat. Wisconsin populations were included in the northern group but were also compared with the remainder of the cultivars in the northern group. The three land races originated in Wisconsin (HC-11), Pennsylvania (Pennscott), and Maryland (Chesapeake).

(diploid vs. tetraploid), geographic origin (location of the breeding program), and selection history (elite vs. land races). The six groups were chosen to form the basis of a set of orthogonal contrasts. The division between northern and southern groups in North America was 37° N lat. Wisconsin populations were included in the northern group but were also compared with the remainder of the cultivars in the northern group. The three land races originated in Wisconsin (HC-11), Pennsylvania (Pennscott), and Maryland (Chesapeake). The groups and contrasts were chosen on the basis of potential or anticipated differences in establishment capacity from frost seeding into a stand of winter wheat. Because this type of seeding has not been previously reported, germplasm groups were largely defined based on known sources of variation in red clover germplasm (Smith et al., 1985).

'Kaskaskia' winter wheat was drilled at 2.96×10^6 seeds ha^{-1} on 11 and 1 October of 2002 and 2003 in Iowa in 19-cm row widths following soybean, and 'Kaltenberg KW39' winter wheat was drilled no-tillage on 9 October 2003 at a seeding rate of approximately 3×10^6 seeds ha^{-1} following soybean in Wisconsin in 18-cm row widths. Liquid dairy (*Bos taurus*) manure (59 g kg^{-1} DM, 221, 38, and 127 kg N, P, and K ha^{-1}) was applied at a rate of 8×10^4 L ha^{-1} to the Wisconsin field before wheat planting. In Iowa, soybean stubble was subjected to a single pass of a tandem disk set to operate at a depth of 5.1 to 7.6 cm before wheat planting. Actual wheat plant densities were 2.34×10^6 and 2.28×10^6 plants ha^{-1} in 2003 and 2004, respectively, in Iowa and 2.78×10^6 in Wisconsin. Wheat plant densities were determined by counting a 1.74-m^2 area in each replicate of the study on 22 and 2 April 2003 and 2004 in Iowa and on 6 April 2004 in Wisconsin. Red clover cultivars were frost-seeded by hand using a mixture of sand and seed to facilitate uniform seed distribution on 24 and 22 March of 2003 and 2004 in Iowa and on 23 March 2004 in Wisconsin at a seeding rate of 850 pure live seed m^{-2}, which averaged about 17 kg seed ha^{-1}. All red clover seed was inoculated before seeding with *Rhizobium leguminosarum* biovar *trifolii* (Nitragin, Inc., Brookfield, WI).

Shortly after green-up, wheat in the no-wheat plots was chemically eliminated using sethoxydim 2-[1-(ethoxyimino)-butyl]-5-[2-ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one at a rate of 0.28 kg a.i. ha^{-1} on 22 and 16 April in 2003 and 2004 in Iowa or 1.2 kg a.i. ha^{-1} of glyphosate [N-(phosphonomethyl)-glycine] on 14 April 2004 in Wisconsin. In the fall of 2002 in Iowa, a broadcast application of 26-67-135 kg ha^{-1} (N-P-K) was applied. In the spring of 2004 in Iowa, a broadcast application of 26-67-67 kg ha^{-1} (N-P-K) was applied. All plots were top-dressed with ammonium nitrate at 45 kg N ha^{-1} on 25 and 31 March in 2003 and 2004 in Iowa and on 2 April 2004 in Wisconsin.

Red clover establishment plant density counts were collected on 7 and 5 May in 2003 and 2004 in Iowa and on 6 May 2004 in Wisconsin. Wheat harvest occurred on 15 and 16 July in 2003 and 2004 in Iowa and 26 July 2004 in Wisconsin. Post-wheat harvest density counts were collected on 18 and 19 July in 2003 and 2004 in Iowa and on 4 August 2004 in Wisconsin. Plant density counts were collected from two 0.1-m^2 quadrats in 2003 and two 0.25 m^2 quadrats in 2004 in each subplot at both sampling times. Red clover forage DM was collected on 22 and 19 August 2003 and 2004 and on 30 September in 2003 and 2004 in Iowa and on 25 August and 15 October in 2004 in Wisconsin by clipping all shoot biomass to a 6-cm stubble height from one 0.25-m^2 quadrat in each subplot.

Data were submitted to analysis of variance assuming all effects to be fixed, except replicates, which were random. Analyses of variance were initially combined across locations and years to test interactions of these factors with cultivars and wheat treatments. When these interactions were significant, separate analyses of variance were computed for individual locations, years, or wheat treatments. Comparisons among red clover cultivar means were conducted by a set of meaningful and orthogonal contrasts structured by the six germplasm sources identified in Table 1 and a protected LSD at the 0.05 significance level. Simple linear regression was used to determine the relationship between forage DM yield and post-wheat harvest plant density.

RESULTS AND DISCUSSION

Abiotic, edaphic, and cultural practices were probably responsible for the varied response observed across years and locations. Air temperature and rainfall deviated from long-term averages during both growing seasons (Table 2). Location main effect and location-by-

Table 2. Mean monthly air temperature and rainfall near Ames, IA, and Prairie du Sac (PDS), WI. Long-term means were computed from data collected in 1951–2004 for Ames and 1971–2000 for Prairie du Sac.

	Air temp.					Rainfall				
Month	Ames 2003	Ames 2004	54-yr mean	PDS 2004	30-yr Mean	Ames 2003	Ames 2004	54-yr mean	PDS 2004	30-yr mean
	°C					mm				
March	2.2	5.6	1.7	2.5	0.3	29	96	52	78	50
April	11.1	11.7	10.0	8.3	7.8	112	61	88	51	80
May	15.6	16.7	16.1	14.3	14.8	122	208	115	219	78
June	20.0	20.0	21.1	18.2	19.9	150	91	127	175	100
July	23.3	22.2	23.3	20.8	22.2	168	50	102	113	97
August	23.3	19.4	22.2	18.4	20.8	25	132	105	124	109
September	16.7	20.0	17.8	16.8	15.9	100	34	80	11	81

Table 3. Analysis of variance probabilities for red clover establishment density, post-wheat harvest density, and forage dry matter yield. The location effect is a test of Ames vs. Prairie du Sac in 2004. The year effect is a comparison of 2003 vs. 2004 at Ames. Dry matter yield is the sum of two 40-d harvest periods following wheat harvest.

Source	df	Establishment	Post-wheat harvest	Dry matter yield
		$P > F$		
Location (L)	1	0.12	0.23	0.81
Year (Y)	1	<0.01	<0.01	0.12
Error a	9			
Cultivar (C)	14	<0.01	<0.01	<0.01
L × C	14	0.69	0.99	0.28
Y × C	14	<0.01	<0.01	0.60
Error b	126			
Wheat (W)	1	<0.01	<0.01	<0.01
L × W	1	<0.01	<0.01	<0.01
Y × W	1	<0.01	<0.01	<0.01
C × W	14	0.04	<0.01	0.55
L × C × W	14	0.69	0.82	<0.01
Y × C × W	14	0.50	0.02	0.59
Error c	135			

cultivar interactions were not significant in 2004, but location-by-wheat and location-by-cultivar-by-wheat interactions were significant (Table 3). Year main effect and interactions were also significant. Data are presented by year and location for all measured variables. Cultivar-by-wheat interactions were not observed in Iowa in 2003 or 2004 for establishment density ($P = 0.44$ and 0.73), post-wheat harvest density ($P = 0.10$ and 0.22), or forage DM yield ($P = 0.22$ and 0.62), so cultivar and wheat data were pooled. In Wisconsin in 2004, cultivar-by-wheat interactions were detected for establishment density ($P = 0.02$) and forage DM yield ($P = 0.04$) but not for post-wheat harvest density ($P = 0.10$), so cultivar-by-wheat means were presented.

Establishment Density

Red clover establishment densities were high in the spring of 2003 near Ames because of the 112 mm of rainfall in April (Table 4). In 2003, above-average air temperature and rainfall in April resulted in rapid red clover germination. The range in density between the high (Marathon) and low (Wis4x) cultivars (160 plants m^{-2}) was equal to the density of the low cultivar (161 plants m^{-2}). In the spring of 2004, establishment densities were low because of the 61 mm of rainfall in April, which reduced and delayed emergence and extended the emergence window. Comparisons between and within cultivar groups exhibited similarities between years in Iowa. Diploid populations had greater establishment densities than tetraploid populations in 2003 and 2004. The European tetraploid trended higher than the local tetraploid but was different only in 2004 in Iowa. Similarly, Cherokee, the southern origin population, trended higher than the northern origin population but was different only in 2003. Differences between Wisconsin and other northern elite germplasms were detected only in 2003. Within Wisconsin elite populations, 'Marathon' established more seedlings than 'C328' in 2003. Due to the general consistency of these effects across locations and years, Cherokee had 19% greater establishment density than northern cultivars ($P < 0.01$), elite lines had 19% greater establishment density than land races ($P < 0.01$), and Wisconsin elite lines had 16% greater establishment density than other elite lines ($P < 0.01$).

Table 4. Mean red clover seedling density in spring (establishment) near Ames, IA, in 2003 and 2004 and near Prairie du Sac (PDS), WI, in 2004. Means are pooled across wheat treatments in Ames because cultivar-by-wheat interactions were not significant.

Cultivar	Origin	Ames 2003	Ames 2004	PDS 2004 No wheat	PDS 2004 Wheat	Mean
		plants m^{-2}				
AC Endure†	Northern	284	29	16	117	134
C328	Wisc.‡	231	31	25	130	118
Cherokee	Southern	270	41	30	117	135
Chesapeake—land race	Eastern	179	38	27	87	96
Cinnamon	Northern	239	33	9	94	115
Dolina-tetraploid	European	181	31	23	54	89
HC-11—land race	Wisc.	219	39	20	57	106
Marathon	Wisc.	321	38	27	165	158
Pennscott—land race	Eastern	181	57	45	126	110
Ram	Northern	189	27	10	127	98
Robust II	Northern	208	35	23	103	106
Scarlett	Northern	288	41	18	113	140
Sienna	Northern	298	36	27	144	146
Starfire	Northern	182	27	10	118	94
Wis4x—tetraploid	Wisc.	161	18	6	75	77
Mean		229	35	21	108	115
LSD (0.05)		54	11	20	51	20
Contrasts		P value				
Diploid vs. tetraploid		<0.01	<0.01	0.17	<0.01	<0.01
Between tetraploids		0.47	0.03	0.11	0.42	0.26
Northern vs. Cherokee§		0.03	0.10	0.19	0.63	<0.01
E‡ vs. LR‡		<0.01	<0.01	0.02	<0.01	<0.01
Wisc. LR vs. eastern LR		0.09	0.07	0.08	0.03	0.72
Between eastern LR		0.96	<0.01	0.08	0.14	0.16
Wisc. E vs. other northern E		0.03	0.50	0.10	0.04	<0.01
Between Wisc. E diploids		<0.01	0.24	0.84	0.18	<0.01

† All cultivars are diploid and elite lines except those noted as tetraploid and land races.
‡ E, elite; LR, land races; Wisc. = Wisconsin.
§ Cherokee represents southern red clover germplasm.

In 2003, the top five cultivars (Marathon, Sienna, Scarlett, AC Endure, and Cherokee) had similar establishment densities, ranging from 270 to 321 plants m^{-2} (LSD 0.05 = 54). In 2004, 'Pennscott' had greater establishment densities (57 plants m^{-2}) than the next closest cultivar (41 plants m^{-2}, LSD 0.05 = 11). A group of 10 cultivars had similar densities that ranged from 31 to 41 plants m^{-2}, of which Marathon, Sienna, Scarlett, and Cherokee were included. In Wisconsin, a group of five cultivars, including Pennscott, Cherokee, Chesapeake, Marathon, and Sienna, were in the top group in the no-wheat plots, with densities ranging from 27 to 45 plants m^{-2} (LSD 0.05 = 20). In the wheat plots, eight cultivars, including Marathon, Sienna, C328, Ram, Pennscott, Starfire, AC Endure, and Cherokee, had densities ranging from 117 to 165 plants m^{-2} (LSD 0.05 = 51). Pooled across cultivar, the no-wheat vs. wheat treatment means were 212 vs. 245 plants m^{-2} in 2003 and 39 vs. 30 plants m^{-2} in 2004 in Iowa and 21 vs. 108 plants m^{-2} in 2004 in Wisconsin.

Post-Wheat Harvest Density

Fewer differences were observed among cultivars and groups for post-wheat harvest density compared with establishment density (Table 5). Differences between diploid and tetraploid cultivars were consistent for establishment and post-wheat harvest red clover plant density. However, other red clover group comparisons were inconsistent between the two measures of red clover plant density. Elite lines vs. land races differed for the two measures of red clover plant density only at Ames in 2003. This was also true for Wisconsin elite lines vs. other elite lines. In 2003, the top five cultivars (Sienna, C328, AC Endure, Marathon, and Scarlett) had similar post-wheat harvest densities, ranging from 249 to 287 plants m^{-2} (LSD 0.05 = 41). In 2004, the cultivars Pennscott, Marathon, and C328 were in the top group (42, 35, and 34 plants m^{-2}; LSD 0.05 = 9) in Iowa. In Wisconsin, the top group of cultivars in the wheat treatment included all cultivars except HC-11, Wis4x, and Dolina (LSD 0.05 = 21), with densities ranging from 48 to 68 plants m^{-2}. Hesterman et al. (1992) reported similar fall red clover densities for medium and 'Michigan Mammoth' (140 and 151 plants m^{-2}) across three Michigan locations with loam, sandy loam, and silty clay soil types.

Pooled across cultivar, the no-wheat vs. wheat treatment means were 260 vs. 199 plants m^{-2} in 2003 and 36 vs. 23 plants m^{-2} in 2004 in Iowa and 24 vs. 53 plants m^{-2} in 2004 in Wisconsin. It is unclear why the wheat plots had higher densities than the no-wheat plots in Wisconsin because in both years we observed the opposite response in Iowa. Nevertheless, the level of mortality (loss in plant numbers from establishment to post-wheat harvest) in the wheat plots in Wisconsin was 51%, compared with 19% and 23% in Iowa in 2003 and 2004, respectively.

Forage Dry Matter Yield

Forage DM yields ranged from 338 to 558 g m^{-2} in 2003 and 419 to 673 g m^{-2} in 2004 in Iowa and from 411 to 771 g m^{-2} in 2004 in Wisconsin in the wheat plots (Table 6). In August 2003, above-average temperature and below-average rainfall adversely affected red clover DM yield during the first growth period after wheat harvest. In September 2004, below-average rainfall at

Table 5. Mean red clover seedling density in summer (post-wheat harvest) near Ames, IA, in 2003 and 2004 and near Prairie du Sac (PDS), WI, in 2004. Means are pooled across wheat treatments in Ames because cultivar-by-wheat interactions were not significant.

Cultivar	Origin	Ames 2003	Ames 2004	PDS 2004 No wheat	PDS 2004 Wheat	Mean
		plants m^{-2}				
AC Endure†	Northern	263	31	31	58	121
C328	Wisc.‡	266	34	30	48	122
Cherokee	Southern	246	32	29	56	115
Chesapeake—land race	Eastern	211	28	27	56	100
Cinnamon	Northern	231	26	16	50	105
Dolina—tetraploid	European	238	25	25	28	105
HC-11—land race	Wisc.	219	30	24	44	102
Marathon	Wisc.	262	35	27	67	123
Pennscott—land race	Eastern	198	42	28	59	101
Ram	Northern	199	23	15	68	93
Robust II	Northern	216	30	20	58	102
Scarlett	Northern	249	32	30	51	116
Sienna	Northern	287	30	31	50	129
Starfire	Northern	181	28	16	65	88
Wis4x—tetraploid	Wisc.	176	17	11	39	78
Mean		229	30	24	53	107
LSD (0.05)		41	9	13	21	14
Contrasts		*P* value				
Diploid vs. tetraploid		0.02	<0.01	0.06	<0.01	<0.01
Between tetraploids		<0.01	0.07	0.05	0.29	<0.01
Northern vs. Cherokee§		0.26	0.43	0.30	0.69	0.12
E‡ vs. LR‡		<0.01	0.11	0.53	0.39	<0.01
Wisc. LR vs. eastern LR		0.42	0.16	0.57	0.13	0.84
Between eastern LR		0.50	<0.01	0.94	0.77	0.95
Wisc. E vs. other northern E		<0.01	0.03	0.12	0.93	<0.01
Between Wisc. E diploids		0.83	0.71	0.70	0.08	0.89

† All cultivars are diploid and elite lines except those noted as tetraploid and land races.
‡ E, elite; LR, land races; Wisc., Wisconsin.
§ Cherokee represents southern red clover germplasm.

Table 6. Mean forage dry matter (DM) yield for red clover cultivars near Ames, IA, in 2003 and 2004 and near Prairie du Sac (PDS), WI, in 2004. Means are pooled across wheat treatments in Ames because cultivar-by-wheat interactions were not significant. Forage DM yield is the sum of two 40-d harvest periods following wheat harvest.

				PDS 2004		
Cultivar	**Origin**	**Ames 2003**	**Ames 2004**	**No wheat**	**Wheat**	**Mean**
		g forage DM m^{-2}				
AC Endure†	Northern	459	593	426	508	511
C328	Wisc.‡	507	565	521	492	528
Cherokee	Southern	558	615	557	665	593
Chesapeake—land race	Eastern	524	590	689	771	600
Cinnamon	Northern	510	592	532	635	559
Dolina—tetraploid	European	338	482	491	411	420
HC-11—land race	Wisc.	503	584	626	602	561
Marathon	Wisc.	527	604	649	573	577
Pennscott—land race	Eastern	506	673	787	568	612
Ram	Northern	535	538	430	607	532
Robust II	Northern	531	541	566	629	551
Scarlett	Northern	486	620	600	484	550
Sienna	Northern	516	501	649	614	539
Starfire	Northern	486	578	558	648	550
Wis4x—tetraploid	Wisc.	466	419	434	576	458
Mean		497	566	568	586	543
LSD (0.05)		51	194	150	156	76
Contrasts		*P* value				
Diploid vs. tetraploid		<0.01	0.01	<0.01	0.01	<0.01
Between tetraploids		<0.01	0.52	0.44	0.04	0.33
Northern vs. Cherokee§		<0.01	0.46	0.84	0.14	0.06
E‡ vs. LR‡		0.97	0.37	<0.01	0.10	0.02
Wisc. LR vs. eastern LR		0.59	0.58	0.09	0.32	0.18
Between eastern LR		0.49	0.39	0.20	0.01	0.76
Wisc. E vs. other northern E		0.35	0.74	0.26	0.20	0.62
Between Wisc. E diploids		0.44	0.69	0.09	0.30	0.21

† All cultivars are diploid and elite lines except those noted as tetraploid and land races.
‡ E, elite; LR, land races; Wisc., Wisconsin.
§ Cherokee represents southern red clover germplasm.

both locations adversely affected DM yield during the second growth period. Dry matter yields were greater in diploid compared with tetraploid populations in both years at all sites. Other comparisons were not consistent across years or locations. In 2003, the top group of cultivars included Cherokee, Ram, Robust II, Marathon, Chesapeake, Sienna, and Cinnamon, with DM ranging from 510 to 558 g m^{-2} (LSD 0.05 = 51). In 2004 in Iowa, the top group of cultivars included all cultivars except Wis4X, with DM ranging from 482 to 673 g m^{-2} (LSD 0.05 = 194). In Wisconsin, the top group of cultivars for the wheat plots included Chesapeake, Cherokee, Starfire, Cinnamon, and Robust II, with DM ranging from 629 to 771 g m^{-2} (LSD 0.05 = 156). Regression analysis of DM yield on post-wheat harvest density indicated no relationship of DM yield to post-wheat harvest density when red clover densities were high (2003). In 2004, a linear relationship was detected for the Iowa ($y = 305 + 8.86x$; $R^2 = 0.65$; $n = 15$; $P < 0.01$) and Wisconsin sites ($y = 382 + 3.83x$; $R^2 = 0.22$; $n = 15$; $P < 0.01$).

CONCLUSIONS

Red clover cultivar performance varies by ploidy, origin, and selection history. In years with favorable germination and emergence conditions, differences in cultivar establishment and forage yield are less pronounced. In years with unfavorable spring conditions for germination and emergence, cultivar differences are pronounced and markedly influence emergence and forage yield. Performance of diploid cultivars exceeds tetraploid in all tested environments. The southern cultivar Cherokee generally had higher performance than the average northern cultivar, most likely due to greater establishment year growth and productivity. Differences across years, locations, and variables were inconsistent for elite and land races. Within different origins and selection histories, large variability exists in cultivar performance. More data are needed to determine if the cultivar-by-wheat interaction is important for screening cultivars for dual grain/forage systems.

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